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Technical Report 145

FOREST BIRD AND NON-NATIVE MAMMAL INVENTORIES AT KA´ĀPAHU, HALEAKALĀ NATIONAL PARK, MAUI, HAWAI´I

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ABSTRACT

Ka'āpahu, Haleakalā National Park was acquired by the National Park Service in 1999. Inventories of vegetation, forest birds, and non-native mammals in this newly acquired area were identified as a priority for the National Park Service. To satisfy the forest bird and non-native mammal inventories, presence or absence and distribution surveys were conducted in 2002. A follow-up forest bird survey was conducted in May 2005. Results of the forest bird surveys showed the presence of four native forest bird species: Maui 'Amakihi (*Hemignathus virens wilsoni*), Maui 'Alauahio (*Paroreomyza montana newtoni*), 'I'iwi (*Vestiaria coccinea*), and 'Apapane (*Himatione sanguinea sanguinea*). Five alien forest bird species were detected: the Japanese Bush-warbler (*Cettia diphone*), Hwamei (*Garrulax canorus*), Red-billed Leiothrix (*Leiothrix lutea*), Japanese White-eye (*Zosterops japonicus*), and Cardinal (*Cardinalis cardinalis*). No endangered bird species were detected. Results suggest that non-native Japanese Bush-warbler, Hwamei and Japanese White-eye may be expanding their range. Results of the non-native mammals survey showed presence of black rats (*Rattus rattus),* small Indian mongooses (*Herpestes auropunctatus*), feral pigs (*Sus scrofa)*, axis deer (*Axis axis*), and feral goats (*Capra hircus*) throughout the transect. We did not capture or record signs of Norway rats (*Rattus norvegicus*), Polynesian rats (*Rattus exulans*), mice (*Mus musculus*), dogs (*Canis lupus*), or feral cats (*Felis catus*) during the survey. However, based on information in other areas throughout the park and on Maui it is very likely that all of these animals occur in Ka'āpahu.

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BACKGROUND

Ka'āpahu, Haleakalā National Park (HALE) was acquired by the National Park Service (NPS) in 1999. Flora and fauna researchers and managers at the National Park Service Biological Inventories Workshop held in January 2000 agreed that existing and historic inventories have documented over 90% of the forest bird and mammal species within all Hawai'i parks with the exception of recent land acquisitions. Following the workshop, the steering committee prioritized inventory needs for each park and identified inventories of vegetation, forest birds and non-native mammals at Ka'āpahu as priorities. The researchers and managers developed study plans for each taxonomic group. The objectives identified in the study plans were to document species and distribution along transects. The primary objective of these inventories was to determine the presence or absence and elevation distribution of forest birds and non-native mammals in Ka'āpahu.

Management goals for Ka'āpahu have not been established and are currently being determined through an Environmental Assessment of an amendment to the park's General Management Plan. Although a mammal inventory of Ka'āpahu was not likely to detect species that would add to the park's mammal diversity, results of this inventory can help in guiding management decisions for the area.

This report includes two separate sections: the Forest Bird Report and the Non-native Mammal Report. While the two reports are inventories of the same area, the differences in the methods, results and discussions warrant two separate reports. The intent of these inventories and this report is to provide a checklist and information about distribution of forest birds and non-native mammals as a baseline for species at Ka'āpahu. The inventories were conducted over a limited time period. As such, results and discussion provide information pertinent to these inventories and should only be compared with other reports on these species if methods were comparable.

Site and Transect Description

Ka'āpahu is located on the southern slope of Haleakalā on the eastern side of the island of Maui in the Hāna District. Ka'āpahu is a 598-hectares (1,478 acres), rectangular finger of land that extends from sea level to approximately 1,273 m (4,200 ft) elevation on the eastern portion of HALE (Figure 1). To the north is the Manawainui area of the park that contains recovering native rainforest. The Pacific Ocean is on the southern boundary. The upper portion of the eastern boundary is adjacent to the park's Kīpahulu Scientific Reserve, one of Hawai'i's protected rainforests that is recovering from damage by non-native species (Anderson and Stone 1993). The west and remainder of the eastern boundaries are surrounded by a combination of privately owned and Hawai'i State lands, including Hawai'i State public hunting lands.

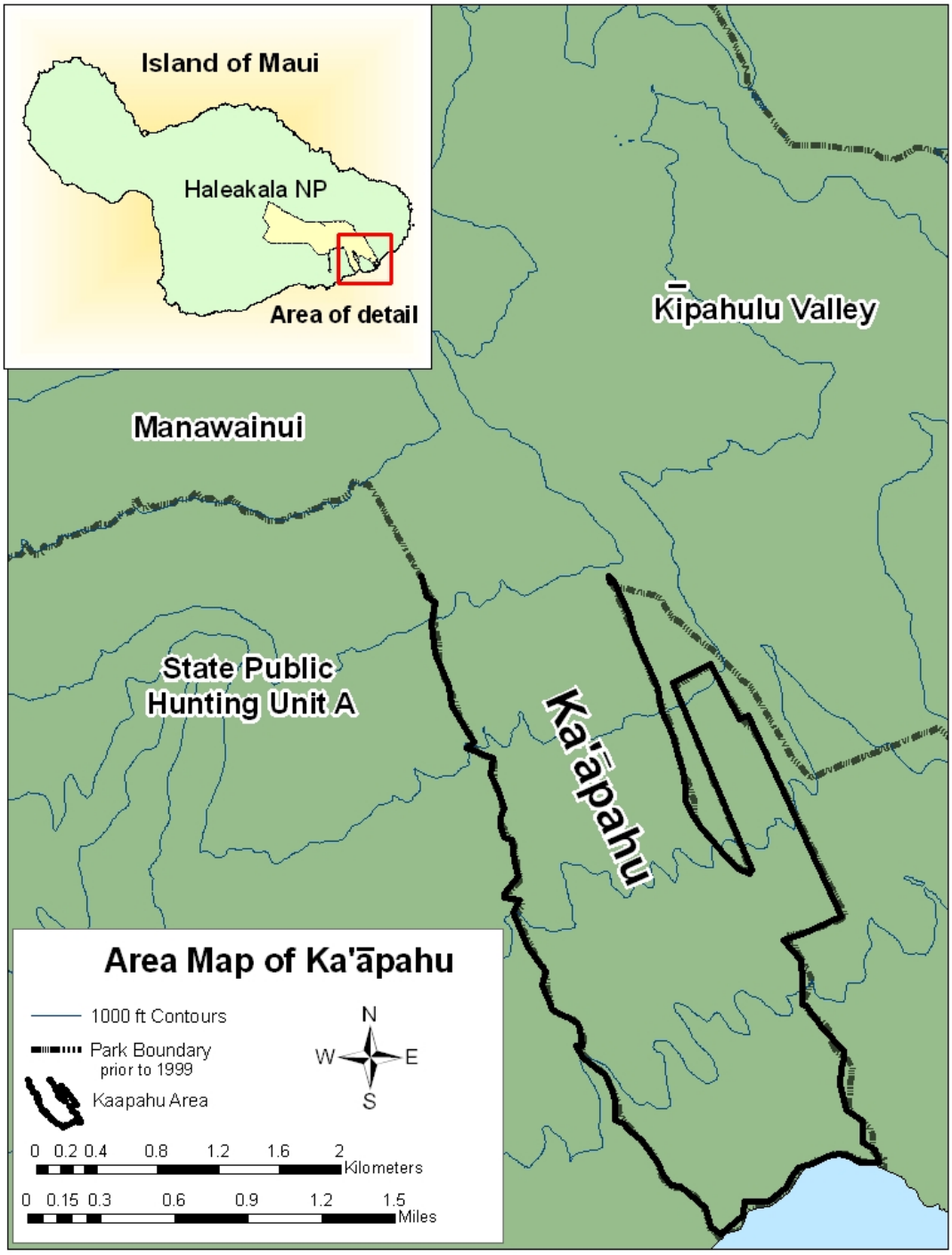

Figure 1. Area map of Ka'āpahu, Haleakalā National Park and vicinity, 2002.

Topographically, Ka'āpahu consists of knife-edge ridges and deep valleys, especially below the 758 m (2,500 ft) contour. The vegetation is diverse and changes with elevation. The upper elevations contain predominately native forest with open koa (*Acacia koa*) canopy, dense native understory and dense native ground cover. The lower elevations consist mainly of non-native vegetation with open koa canopy, open non-native understory, and open non-native ground cover that is highly damaged by feral goats and pigs (Welton and Haus 2005).

Unlike other areas of HALE, Ka'āpahu is not enclosed by a feral animal control fence and is not actively managed for resource protection. NPS is in the process of building a feral animal control fence on the northern boundary of Ka'āpahu and is expected to complete this fence in 2007 (Ron Nagata, pers. comm.).

Transects did not exist in Ka'āpahu prior to these surveys. A single transect was established along which both the forest bird and non-native mammal inventories were conducted (Figure 2). The transect is essentially a line running through the forest. Flagging tape marks the route and is used to indicate distances from the endpoints and between stations. Much of the terrain in Ka'āpahu is dangerous and difficult to traverse. Thus, the process of establishing the transect was laborious and slow, and the transect route was determined by selecting an area safe for human travel.

The transect traverses an elevation gradient in a north-south direction from approximately 1,180 m (3,880 ft) elevation to sea level. Stations were set and recorded with a Global Positioning System (GPS) using the Universal Transverse Mercator projection, North American Datum 1983, Zone 4N. All data were collected in field notebooks and housed at HALE.

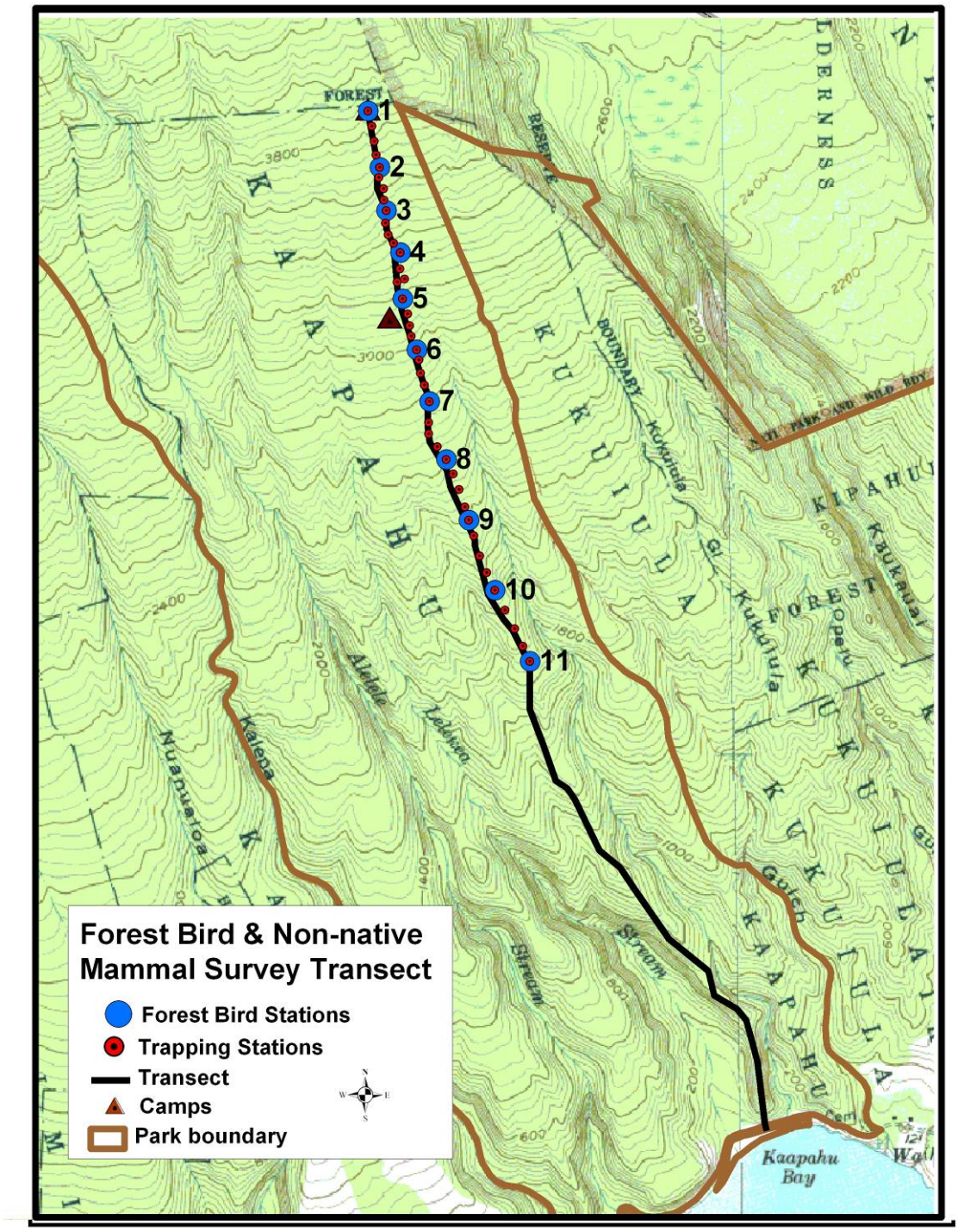

Figure 2. Forest bird (2002 and 2005) and non-native mammal (2002) transect and survey stations at Ka'āpahu, Haleakalā National Park. Numbers indicate forest bird stations.

FOREST BIRD REPORT

By Cathleen Natividad Bailey and Timothy Paulokaleioku Bailey

Introduction

Researchers, managers and a steering committee at the National Park Service Biological Inventories Workshop held in January 2000 identified the need to inventory forest bird populations at Ka'āpahu as a high priority. The objectives of this inventory were to document the presence or absence and distribution of forest birds at Ka'āpahu.

Nine species of native honeycreepers, five of which are federally listed as endangered, and several non-native species have been detected in the rainforests of HALE and Maui (Scott et al. 1986, HALE unpubl. data).

Maui 'Amakihi (*Hemignathus virens wilsoni*), 'I'iwi (*Vestiaria coccinea*), and 'Apapane (*Himatione sanguinea*) are relatively common native forest birds that are detected in HALE rainforests at elevations ranging from 757 to 2,121 m (2,500 to 7,000 ft). The Maui 'Alauahio (*Paroreomyza montana newtoni*) is commonly detected in the higher elevations from 1,515 m to 2,121 m (5,000 ft to 7,000 ft) and occasionally detected as low as 757 m (2,500 ft) in the rainforests of HALE (Scott et al. 1986, HALE unpubl. data).

Two endangered species are regularly detected during annual surveys in HALE rainforests. Maui Parrotbill (*Pseudonestor xanthophrys*) is detected regularly from 1,363 to 1,970 m (4,500 to 6,500 ft), although in very low numbers. 'Ākohekohe (*Palmeria dolei*) is relatively common at HALE in Manawainui, Kīpahulu Valley and Upper Hāna Rainforest from 1,667 to 1,970 m (5,500 to 6,500 ft) elevation (Scott et al. 1986, HALE unpubl. data).

Three endangered species are extremely rare and have been detected at HALE only during intensive, focused searches. These species are the Maui Nukupu'u (*Hemignathus lucidus affinis*), Maui 'Akepa (*Loxops coccineus ochraceus*), and Po'ouli *(Melamprosops phaeosoma,* (Scott et al. 1986, Reynolds and Snetsinger 2001).

Maui Nukupu'u is thought to prefer koa-'ōhi'a forests with well-developed understories between 1,450 and 2,000 m (4,785 and 6,600 ft) elevation (Scott et al. 1986). Only one Nukupu'u was seen in the early 1980s during the Hawai'i Forest Bird Survey (HFBS), at 1,600 m (5,280 ft) elevation in wet 'ōhi'a forest with native understory. The population of the Maui Nukupu'u was estimated at 28 $\pm$ 56 individuals (95% CI) in the early 1980s (Scott et al. 1986). The most recent sighting of the Maui Nukupu'u occurred during intensive searches in Hanawī Natural Area Reserve at 1,890 m (6,200 ft) on the northern slope of Haleakalā in 1996 (Reynolds and Snetsinger 2001). However, the existence of this species is still questionable (Pratt and Pyle 2000, Pratt et al. 2001).

Populations of 'Akepa on Maui were estimated at 230 $\pm$ 290 (95% CI) individuals in the early 1980s with a patchy, relictual distribution in East Maui rainforests (Scott et al. 1986). The last visual detection of the 'Akepa was in 1988 and the last auditory detection was at 1,872 m (6,140 ft) in 1995 during intensive searches in Kīpahulu Valley (Reynolds and Snetsinger 2001). Auditory detections require visual confirmation because 'Akepa

songs can be confused with songs of Maui Parrotbills. Therefore, the detections in Kīpahulu were not confirmed. The current population of 'Akepa is unknown, and may possibly be extinct.

The Po'ouli was discovered in 1973 and was confined to a single location in wet 'ōhi'a forest above 1,500 m (4,920 ft) of Haleakalā (Casey and Jacobi 1974). The Po'ouli population was estimated at 140 $\pm$ 280 (95% CI) individuals in the early 1980s (Scott et al. 1986). In 1993, a single bird was seen on the northeastern slope of Haleakalā (Reynolds and Snetsinger 2001). The U. S. Fish and Wildlife Service (USFWS) and the Hawai'i Department of Land and Natural Resources (HDLNR) formulated a massive undertaking to prevent the species from becoming extinct and created the Maui Forest Bird Recovery Project in 1995 (USFWS and HDLNR 1999). In 1996, only six individuals were known; they occupied a narrow stretch of native forest within the Hanawī Natural Area Reserve and Haleakalā National Park (Reynolds and Snetsinger 2001). By 1999, only three individuals were known (USFWS and HDLNR 1999). Despite intensive searches and playing of callbacks, sightings of Po'ouli have not been recorded since September 2004 according to the Maui Forest Bird Recovery Project (MFBRP; Kirsty Swinnerton, pers. comm.); the species is possibly extinct.

Methods

Eleven forest bird monitoring stations were set and numbered at 200 m intervals along the transect. The stations ranged from 545 m (1,800 ft) to 1,176 m (3,880 ft) elevation (Figure 2). The original survey was conducted from October 8-10, 2002. A follow-up survey was conducted on May 11, 2005. This seemingly short period of time is common for conducting forest bird surveys in rainforest areas of Hawai'i (Rick Camp, pers. comm.). While attempts were made to inventory the area more often, these were the only dates that could be surveyed. Only one qualified primary surveyor was available during these times. Access to Ka'āpahu is logistically difficult because of the many steep cliffs and deep valleys, requiring transportation by helicopter. The unpredictable, rainy weather forced cancellation of planned surveys and helicopter flights.

Forest birds were surveyed using the variable circular plot (VCP) method utilized by HFBS (Scott et al. 1986). This method is used in forest bird surveys across the state by a variety of state and federal agencies and organizations, including HALE. Surveys were conducted during the morning hours beginning just after sunrise and ending by noon. All birds seen or heard during an eight-minute count period at each station were recorded with the detection type (audio, visual or combined detection) and the distance to the bird when first detected, estimated to the nearest meter. Observations between stations were not recorded.

A primary surveyor and secondary surveyor recorded forest bird observations at each station. The primary surveyor was an experienced observer trained to recognize all bird species known to occur on Maui. Training included calibration for consistency in bird identification and distance estimation. The secondary surveyor was less experienced in forest bird surveys. Although both primary and secondary surveyors collected field data, only data collected by the primary surveyor were used as the principal data set. Voucher specimens of birds were not collected.

Data from field notebooks were entered into the Avian Monitoring Entry Form (AMEF) database program from the Hawai'i Forest Bird Interagency Database Project (HFBIDP). The AMEF program calculates summaries of bird detections.

The number of birds per station (BPS) and percent of occurrence were calculated according to the AMEF manual (HFBIDP 2004). BPS is calculated by dividing the number of bird detected by the number of stations surveyed. Percent of occurrence is calculated by dividing the number of stations occupied by birds by the number of stations surveyed.

Results

Species composition was the same for 2002 and 2005. Four native species and five non-native species were detected during both surveys. Native species detected were Maui 'Amakihi, Maui 'Alauahio, 'I'iwi, and 'Apapane. Non-native species detected were Japanese Bush-warbler (*Cettia diphone*), Hwamei (*Garrulax canorus*), Red-billed Leiothrix (*Leiothrix lutea*), Japanese White-eye (*Zosterops japonicus*), and Northern Cardinal (*Cardinalis cardinalis*; Table 1). Endangered species (Maui Parrotbill, Nukupu'u, 'Akepa, 'Ākohekohe and Po'ouli) were not detected.

Number of detections and BPS were calculated and examined for both surveys (Table 1). Results from 2005 varied from 2002 for several species. Of the nine species detected, 'Apapane was the most common bird detected in 2002 (4.00 BPS, 44 detections), but was the fourth most common bird detected in 2005 (3.18 BPS, 35 detections). Japanese Bush-warbler was the most common bird detected in 2005 (5.09 BPS, 56 detections), but was the fifth most common bird detected in 2002 (2.27 BPS, 25 detections).

'I'iwi detections were notably less in 2005 (0.55 BPS, 6 detections) than in 2002 (1.91 BPS, 21 detections). Also, 'I'iwi was the least common bird detected along with Maui 'Alauahio. Conversely, detection of Japanese Bush-warbler and Japanese White-eye were markedly higher in 2005 (5.09 BPS, 56 detections; 4.82 BPS, 53 detections, respectively) than in 2002 (2.27 BPS, 25 detections; 2.64, 29 detections, respectively). Maui 'Alauahio was the least common bird detected in 2002 (0.73 BPS, 6 detections) and 2005 (0.55 BPS, 6 detections).

Percent occurrence (i.e., number of stations occupied) also varied slightly between surveys. In 2002, Japanese Bush-warbler, Red-billed Leiothrix, Japanese White-eye, and Maui 'Amakihi had the highest percent of occurrence (81.8%, 9 of 11 stations). Hwamei and Maui 'Alauahio had the lowest percent of occurrence (27.3%, 3 of 11 stations) in 2002. In 2005, Japanese Bush-warbler and Japanese White-eye had the highest percent of occurrence, occupying all 11 stations. As in 2002, Maui 'Alauahio had the lowest percent of occurrence in 2005 (36.4%, 3 of 11 stations). Of all species detected, differences in Hwamei are most notable. Hwamei occurred at more than twice the number of stations in 2005 than in 2002.

The distribution of native bird species in 2005 varied slightly from 2002 (Figure 3). Maui 'Amakihi was the only native species detected along the entire transect in both 2002 and 2005 (Figure 3a). Maui 'Alauahio were detected at the three uppermost stations in 2002 (Figure 3b). However, detections of Maui 'Alauahio in 2005 were at a larger elevation range at four stations, with a visual confirmation at the lowest station. 'I'iwis were detected at higher elevation stations during both surveys (Figure 3c). 'Apapane were detected at the eight highest stations in 2002, and along the entire transect in 2005 (Figure 3d).

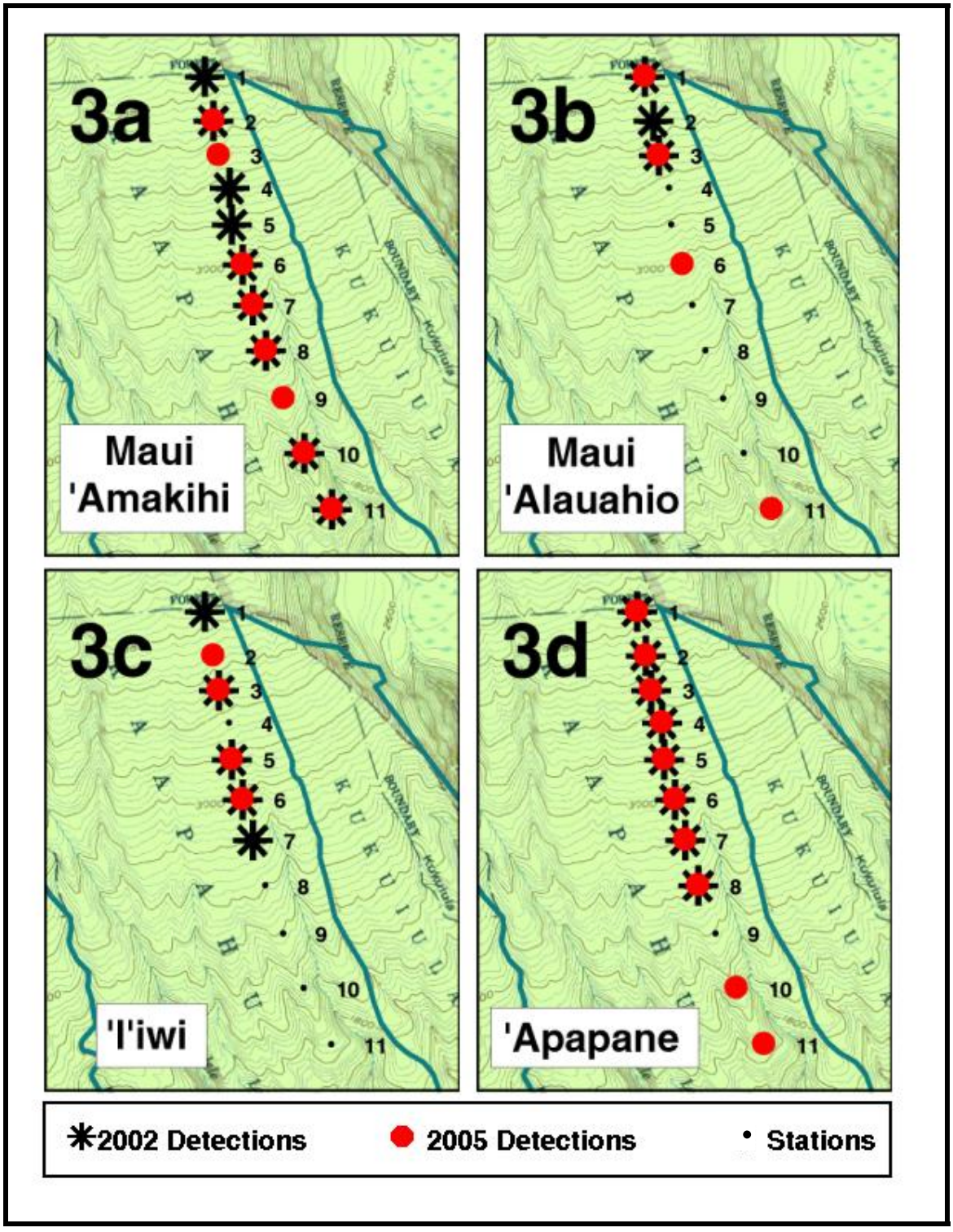

Figure 3. Distribution of native bird species detected along the transect during surveys, Ka'āpahu, Haleakalā National Park, 2002 and 2005.

The distribution of non-native birds in 2005 also varied slightly from 2002 (Figure 4). Japanese Bush-warbler (Figure 4a), Red-billed Leiothrix (Figure 4b), and Japanese White-eye (Figure 4c) were detected from the uppermost to the lowest elevation stations of the transect in 2002 and 2005, although not at all stations. Hwamei was detected at the lower elevation stations in 2002, but from the uppermost to the lowest elevation stations of the transect in 2005 (Figure 4d). Northern Cardinal was detected from the uppermost to the lowest elevation stations in 2002, but not at all upper elevation stations in 2005 (Figure 4e).

Table 1. *Summary of observations for bird surveys at Ka'āpahu, Haleakalā National Park, October 2002 and May 2005.*

Species	**Birds per Station**		**Number of Detections**		**Percent of Occurrence**	
	2002	**2005**	**2002**	**2005**	**2002**	**2005**
Japanese Bush-warbler	2.3	5.1	25	56	82	100
Hwamei	1.1	1.7	12	19	27	73
Red-billed Leiothrix	2.5	3.6	27	40	82	91
Japanese White-eye	2.6	4.8	29	53	82	100
Northern Cardinal	1.1	0.7	12	8	73	45
Maui 'Amakihi	2.9	2.2	32	24	82	73
Maui 'Alauahio	0.7	0.6	8	6	27	36
'I'iwi	1.9	0.6	21	6	45	36
'Apapane	4.0	3.2	44	35	73	91

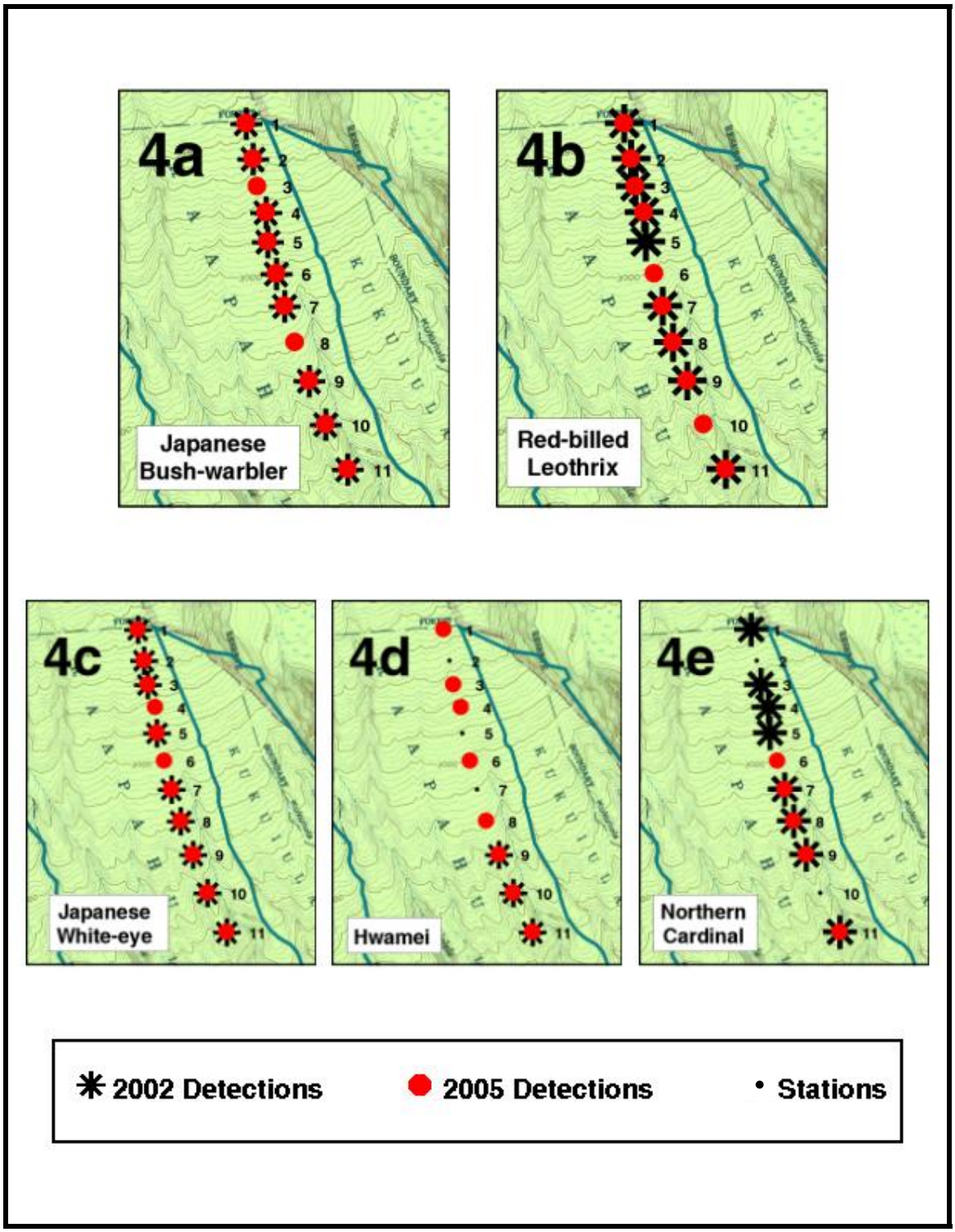

Figure 4. Distribution of non-native bird species detected along the transect during surveys, Ka'āpahu, Haleakalā National Park, 2002 and 2005.

Discussion and Recommendations

Conducting a follow-up survey in 2005 offered a more complete understanding of forest birds at Ka`āpahu. Although species composition did not vary between 2005 and 2002, differences in BPS (relative density) and distribution of some species were observed. These differences may be caused by a variety of factors.

Two possible reasons for differences in BPS and number of detections between the 2002 and 2005 surveys are seasonality differences and the effect of a large-scale koa defoliation. The 2002 Ka'āpahu survey was conducted in the post-breeding season in October, while the 2005 survey was conducted during the hatching/fledging season in May. Surveys were not conducted during the same season because of logistical difficulties. Bird vocalizations and detection probability may differ between seasons and may account for the differences we observed. Additionally, about 70% of the koa in the rainforests of HALE defoliated in 2004 (P. Welton, pers. comm.); birds may have responded to this change in forest condition.

Surveys conducted in Kīpahulu Valley by HALE NPS staff may offer some insight to the differences in relative density of 'I'iwi, which was notably lower in 2005 than in 2002 at Ka'āpahu. Surveys were not conducted in Kīpahulu in 2002; therefore, 2001 data were examined. Detections from stations at similar elevations along the western end of Kīpahulu Valley also show declines in 'I'iwi detections. Preliminary analysis of the data show that in Kīpahulu, detections of 'I'iwi in 2005 (0.9 BPS) were far less than in 2001 (2.41 BPS). Unlike Ka'āpahu, data from Kīpahulu were collected during the same season in 2001 and 2005, reducing the possible effects of seasonal variability on detection. The lowered BPS of 'I'iwi in relation to the koa defoliation that occurred at Ka'āpahu and Kīpahulu should be examined.

Two native bird species in 2005 were detected at elevations lower than typically observed. The Maui 'Alauahio and 'Apapane were seen at approximately 545 m (1,800 ft) in predominately non-native forest. Both are typically observed at elevations above 757 m (2,500 ft) in predominately native forest (Scott et al. 1986, HALE unpubl. data). These atypical observations of Maui 'Alauahio and 'Apapane may be attributed to the low presence of malaria and steep topography of Ka'āpahu. Interim data on avian malaria at Ka'āpahu shows a very low presence of malaria in birds captured at 970 m (3,200 ft). None of the mosquitoes captured at Ka'āpahu tested positive for malaria (Aruch et al. 2005, HALE unpubl. data). The topography at Ka'āpahu contains many steep ridges and gullies that may prohibit standing water that could harbor mosquito larvae. Also, Ka'āpahu is at the eastern most end of the tradewind zone. Wind speeds average 7.5-8 m/s (16.8-17.9 mph) and have been recorded as high as 17.9 m/s (40 mph; AWS Truewind 2004). The wind may prevent numbers of mosquitoes from becoming high, thereby decreasing the prevalence of malaria. Additionally, the topography at Ka'āpahu may make travel to lower elevations easier for these bird species. Ka'āpahu is relatively steeper than other rainforest areas of Maui. The distance for birds to fly from upper elevations to lower elevations may be less than the distance to travel through similar elevation differences in other rainforest areas of Maui.

Our surveys suggest that non-native birds may be expanding their range. The numbers of birds per station of Japanese Bush-warbler and Japanese White-eye in 2005 were almost twice as high as in 2002. These higher numbers could translate to expansion into higher elevations as lower elevations become saturated. Japanese Bush-warbler is now being detected at elevations as high as 2,121m (7,000 ft) in Haleakalā Crater (pers. obs.). Hwamei was detected at higher elevation stations in 2005 than in 2002. Data from the western transect in Kīpahulu Valley shows that Hwamei occupied more stations in 2005 than in 2001 and were detected at elevations as high as 1,030 m (3,400 ft; HALE unpubl. data). Further research is needed to make inferences on trends in non-native bird ranges.

Northern Cardinals were not detected at higher elevation stations in 2005. However, Northern Cardinals were detected at these stations in 2002 and after the survey (pers. obs.), and continue to occupy these areas of Ka'āpahu.

We did not detect endangered birds along the transect during this survey. The chance of detecting endangered birds was low since the highest point of the transect is at a relatively low elevation (1,175 m/3,880 ft). 'Ākohekohe and Maui Parrotbill are found in the adjacent Kīpahulu Valley and Manawainui. However, the lowest elevations Maui Parrotbills are found are 1,212 m (4,000 ft) in Kīpahulu and 1,670 m (5,600 ft) in Manawainui. The lowest elevation 'Ākohekohe are found are at 1,576 m (5,200 ft) in both Kīpahulu and Manawainui (HALE unpubl. data). It is unlikely that Nukupu'u, 'Akepa, or Po'ouli occur in Ka'āpahu. As stated earlier, these species are extremely rare and were only detected, at extremely low numbers during intensive searches in Maui rainforests. Although rare birds have been detected while conducting VCP counts, most rare birds can not be detected using this method. Other methods for detecting rare birds should be explored (Scott et al. 1986, Reynolds and Snetsinger 2001).

Several non-native species were observed in the adjacent areas and may occur at Ka'āpahu. Nutmeg Mannikins (*Lonchura punctulata*) were captured in December 2002 during mosquito surveys in Kīpahulu Valley (Aruch et al. 2005, HALE unpubl. data). Nutmeg Mannikins have not been detected during annual forest bird surveys in Kīpahulu. Nutmeg Mannikins could occur in Ka'āpahu and not be detected during VCP surveys. According to an ornithological survey of Manawainui (Stemmerman 1976), Nutmeg Mannikins avoided densely forested areas and were occasionally found on the periphery of forested regions. House Finches (*Carpodacus mexicanus*) have been detected in low rates in Kīpahulu and were observed in Manawainui (Stemmerman 1976, HALE unpubl. data). Spotted Doves (*Streptopelia chinensis*), Zebra Doves (*Geopelia striata*), Common Mynas (*Acridotheres trsitis*), House Sparrows (*Passer domesticus*) and African Silverbills (*Lonchura cantans*) are common throughout low elevation areas of Maui (Stemmerman 1976, Pratt et al. 1987, Hawai'i Audubon Society 1996) and probably occur in Ka'āpahu at elevations that are below our lowest station (545 m/1,800 ft) and mostly at sea level.

We recommend that regular surveys of forest birds in Ka'āpahu should be conducted. Surveys along this Ka'āpahu transect should be incorporated into the park's annual forest bird surveys. Also, data from the park's current forest bird monitoring program in Kīpahulu should be examined. This could provide valuable information on species composition, distribution, densities and trends of native and non-native forest birds and invasions of non-native forest birds in the park.

NON-NATIVE MAMMAL REPORT

By Cathleen Natividad Bailey, Timothy Paulokaleioku Bailey and Gale Plana

Introduction

Researchers, managers and a steering committee at the National Park Service Biological Inventories Workshop held in January 2000 identified the need to inventory non-native mammal populations at Ka'āpahu as high priority. The objective of this inventory was to document the presence or absence and distribution of non-native mammals at Ka'āpahu.

There are four documented species of rodents in Hawai'i: black or roof rat (*Rattus rattus*), Norway rat (*R. norvegicus*), Polynesian rat (*R. exulans*), and house mouse (*Mus musculus*). Black rats became established in the late 1800's (Kramer 1971, Tomich 1986). Norway rats and mice were established in Hawai'i shortly after the arrival of European explorer Captain James Cook in 1778. Norway rats are predominately found at low elevations and are rare in high-elevation Hawaiian forests (Tomich 1986). Polynesian rats came on boats with early Polynesian settlers around 400 A.D. (Kirch 1982). Polynesian and black rats are well adapted to the ecological conditions in rainforests on Maui (Sugihara 1997). All rodent species are caught in cage-type predator control traps at HALE at elevations from sea level to 3,037 m (10,023 ft), with black rats being the predominate species (HALE unpubl. data).

The small Indian mongoose (*Herpestes auropunctatus*) was released in Hawai'i in 1883 as a biological control for rats (Tomich 1986). Mongooses occur throughout all areas of HALE with populations highest at sea level and are scarce but present at the park's 3,037 m (10,023 ft) summit (Natividad Hodges 1994, Natividad Hodges and Nagata 2001). Trapping rates suggest that mongooses occur in the rainforests of HALE in high numbers from 1,515 to 2,060 m (5,000 to 6,800 ft) elevation (HALE unpubl. data).

Domestic cats (*Felis catus*) arrived in the Hawaiian Islands with European explorers and settlers in the late 1800s and became feral (Kramer 1971, Tomich 1986). Feral cats range from sea level, where populations are higher, to sub-alpine areas of Maui and Hawai'i (Simons 1983, Natividad Hodges 2001, Winter 2003). At HALE, cats occur in relatively small numbers in the sub-alpine cinder deserts of Haleakalā Crater. Cats and cat signs are observed throughout the rainforests of HALE (HALE unpubl. data).

Pigs (*Sus scrofa*) of Asian ancestry were brought to the Hawaiian Islands in 400 A.D. and English pigs (commonly known as European boars) were introduced in 1778 by Captain James Cook (Tomich 1986). These domestic pigs became feral and dispersed throughout all ecosystems in Hawai'i (Stone and Loope 1987). Pigs occur throughout rainforest areas of Maui. Over 1,000 pigs were removed from the rainforests of HALE from 1986 to 2002 (HALE unpubl. data). Signs and sightings of pigs continue to occur throughout HALE.

Axis deer (*Axis axis*) were brought to the Hawaiian Islands in 1867. In 1959, five to seven deer were introduced to the Pu'u O Kali area of Maui (Tomich 1986, Waring 1997, Anderson 2003). Axis deer are now widespread on Maui and occur near Ka'āpahu. Population estimates in 2000 were 2,000 to 4,000 individuals on Maui with the highest numbers of deer occurring along the southern flank of Haleakalā (Anderson 2003).

Thirty-two axis deer were removed from the dry, sub-alpine forests of HALE near 2,121 m (7,000 ft) elevation and adjacent areas from 1989 to 2001 (HALE, unpubl. data). Axis deer are currently spreading and increasing in numbers on Maui, and pose a new and serious threat to natural areas.

Domestic goats (*Capra hircus*) were brought to the Hawaiian Islands by Captain James Cook in 1778 and became feral (Yocum 1967). Large herds of feral goats exist at Ka'āpahu and on adjacent lands. Goats and signs of goat presence such as vegetation damage, feces, and habitat disturbance have been observed at Ka'āpahu during cursory surveys conducted prior to this inventory (HALE unpubl. data).

Methods

Forty-one monitoring stations were set and numbered at 50 m (164 ft) intervals along the transect (Figure 2). The survey was conducted in two parts. The upper portion from 1,180 to 920 m (3,880 to 3,040 ft) elevation was surveyed August 19-22, 2002. The lower portion from 920 m (3,040 ft) elevation to sea level was surveyed October 8-10, 2002. While attempts were made to inventory the area more often, these were the only dates that could be surveyed. The dangerous terrain made trap setting difficult. Access to Ka'āpahu is logistically difficult, requiring transportation by helicopter. The unpredictable, rainy weather forced cancellation of planned surveys and helicopter flights.

Surveyors were based from a camp just below the upper boundary to conduct the survey of the upper portion of the transect and moved to a lower elevation temporary camp to survey the lower portion of the transect. Transportation to the lower elevation camp was by helicopter; a landing zone platform was built to accommodate helicopter travel. Helicopter operations for mammal survey work were scheduled to coincide with transportation of staff performing other surveys and HALE projects.

The original mammal survey plan called for more intensive trapping efforts, to be conducted by technicians hired specifically to conduct the trapping. There was difficulty in finding qualified technicians during the specified period. Therefore, in-house HALE staff conducted the work for a shorter time period than planned. Vouchers specimens of mammals were not collected, due to the difficulty of preserving the specimens in the field. Photos were taken, but these were not of voucher quality and are not included in this report.

Small Mammals

Trapping Methods

Trapping was utilized to determine the presence or absence of small mammals. The types of traps used in the survey were snap traps (Victor® # M201) and soft-catch leg hold (Victor® #1) traps. Snap traps were used to capture rats and mice. Leg hold traps were used to capture mongooses and cats. Experience from an ongoing 15-year mammal trapping program conducted at HALE indicated that mongooses enter cage traps without hesitation, and are also caught in leg hold traps. Conversely, cats are wary of visible traps and quickly learn to avoid traps from which they escape. Leg hold traps can be set in such a manner that is not visible to cats and are more efficient at capturing cats. Thus, cage

traps were not used. To minimize conditioning of cats to leg hold traps, pre-baiting did not occur.

Trapping occurred for a total of 288 trap days. One trap day was defined as one trap set for one day. One snap trap and one leg hold trap were strategically placed at each station. Traps were anchored to available substrate to prevent them from being moved by animals. Trapping occurred for four consecutive days at 21 stations in the upper portion and three subsequent days at 20 stations along the lower portion of the transect. Traps were not set at elevations below 570 m (1,880 ft) to avoid disturbance by the general public, which access the area below this elevation.

Traps were baited with a two-to-one mixture of cat food and dog food. This bait mixture has proven to be effective for capturing cats and mongooses at HALE. Bait was placed on snap traps as directed by the manufacturer. Leg hold traps were deployed so that the traps were not visible to predators. Bait for each leg hold trap was placed so as to compel animals to step and trigger the trap. Field data collected included: date, observer, station number, trap type, catch ID number, species caught, age, and sex.

Necropsy Methods

Animals were necropsied in the field by trained staff. Rats were killed by the action of the snap traps. Mongooses were killed by a single gunshot to the head (causing instantaneous death). Sex for all animals was determined by examining the genitalia of the animal.

Rat necropsies consisted of external measurements only. Standard mammal measurements commonly used for study skins in museum collections were used to record external measurements (Verts and Carraway 1998). External measurements included lengths of tail, body, hind foot, and ear. Ages of female black rats were divided into two categories based on size. Females with a body size less than 12.8 cm (5.0 in) were considered juveniles, females larger than that were considered adults. Ages of male black rats were determined by size and reproductive status of the rats. Juvenile male black rats were those with a body size less than 14.1 cm (5.6 in) and testes not in the scrotal position. Subadult male black rats were those with a body size greater than 14.1 cm (5.6 in) and testes not in the scrotal position. Adult males were those with a body size greater than 14.1 cm (5.6 in) and testes in the scrotal position (Strecker et al. 1962).

Necropsies for mongooses included external measurements and an assessment of general health, reproductive status, and diet. General health of an animal was determined by examining the occurrence of fat under the skin (subcutaneous), throughout the mesentery, and around the organs. Reproductive status of males and females were determined by examining reproductive organs (Larson and Taber 1980). Status of males was determined by examining condition of the testes. Descended testes, those located in the testicular sack, indicated adult males that were sexually mature. Inguinal testes, those located within the body cavity, indicated young males that were not sexually mature. Reproductive status of females was noted by examining the uterus. A non-distended uterus indicated the female had not had young (nulliparous). A distended uterus or teats with signs of lactation indicated that the female had young, i.e., was parous (Nellis and Everard 1983, Nellis 1989, Verts and Carraway 1998).

Ages of mongooses were based on size and reproductive status. Mongooses that weighed less than 300 g (10.6 oz) were considered juveniles. Subadult males were those that weighed more than 300 g (10.6 oz), had a body length greater than 28.0 cm (11 in), and were sexually immature. Males that weighed more than 300 g (10.6 oz), had a body length greater than 28.0 cm (11 in), and were sexually mature were considered adult males. Subadult females were those weighing more than 300 g (10.6 oz), with a body length greater than 23.0 cm (9.0 in), and nulliparous. Adult females were those weighing more then 300 g (10.6 g), with a body length greater than 23.0 cm (9.0 in), and either parous, pregnant or lactating (Nellis and Everard 1983, Nellis 1989, Hays 2000).

Large Mammals

The large mammal survey was conducted along the entire transect. Large mammal sign characterized the presence or absence for each species. If signs were present, location, type of sign, and the status of the feces - whether fresh, intermediate, or old - were recorded. For visual observations of large mammals, observers recorded location, date, time, species, sex, age, and approximate size. Data recorded for audio detections of large mammals included location, date, time and species.

Pigs characteristically plow the ground in search for food, and their feces are large and distinctive. Habitat disturbance, fecal droppings, and direct audio or visual observations all indicated the presence of pigs in the area.

It is difficult to distinguish between presence of feral goats and axis deer based on signs such as feces, tracks, and vegetation damage (Waring 1997, Anderson 2003). Therefore, feces and tracks observed indicated the presence of either goats or deer. Furthermore, the presence of goats or deer was confirmed by audio and visual observations. Axis deer are secretive during the day and difficult to encounter. They rub their antlers against trees and shrubs causing damage to the outer bark; such rubbing is of deer (pers. obs.). The presence of axis deer was also confirmed by investigating damage on trees and shrubs along the transect and including it in the survey data.

Results

The surveys detected the presence of five mammal species: black rat, mongoose, feral pig, axis deer, and feral goat. This survey did not detect the presence of other mammals that are likely to be present in the area, such as Norway rats, Polynesian rats, house mice, cats, or dogs (*Canis lupus*).

Small Mammals

Trapping

Eight black rats and five mongooses were trapped at 11 stations over 288 trap days. (Table 2, Figure 5). Black rats were caught at stations ranging in elevation from 756 to 1,170 m (2,480 to 3,840 ft). Mongooses were caught at stations ranging in elevations from 773 to 1,067 m (2,550 to 3,520 ft).

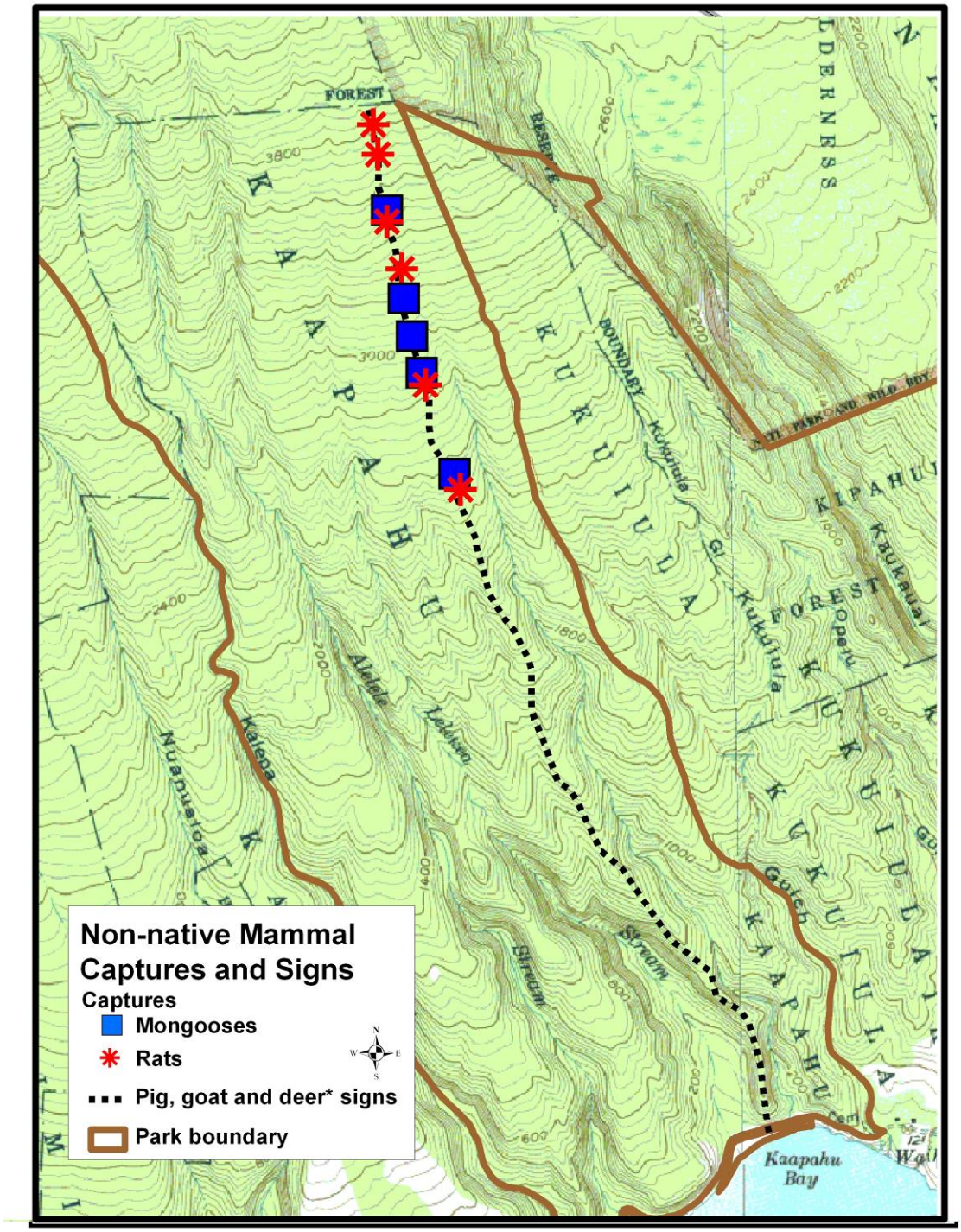

Figure 5. Non-native mammal captures and signs at Ka'āpahu, Haleakalā National Park, 2002. *Only feces and tracks of deer were observed.

Table 2. *Summary of small mammal trapping at Ka'āpahu, Haleakalā National Park, 2002*

Species	Elevation (ft)	Station ID	Species ID
Rattus rattus	2480	1500M	RR8
Rattus rattus	2860	1150M	RR6
Rattus rattus	2860	1150M	RR7
Rattus rattus	3290	650M	RR5
Rattus rattus	3480	450M	RR4
Rattus rattus	3480	450M	RR3
Rattus rattus	3720	150M	RR2
Rattus rattus	3840	50M	RR1
Herpestes auropunctatus	2550	1450M	HA5
Herpestes auropunctatus	2920	1100M	HA4
Herpestes auropunctatus	3040	950M	HA3
Herpestes auropunctatus	3190	800M	HA2
Herpestes auropunctatus	3520	400M	HA1

Necropsy

Of the eight rats caught, four were adult males, one was a juvenile male, one was a subadult male, and two were juvenile females (Table 3). Two of the adult male rats were caught at one station. External measurements of rats are shown in Table 3.

Table 3. *External measurements for black rats (Rattus rattus) trapped at Ka'āpahu, Haleakalā National Park, 2002.*

Species ID	Sex	Age	Tail (cm)	Body (cm)	Hind foot (cm)	Ear (cm)
RR6	F	Juvenile	11.9	11.0	1.2	2.4
RR8	F	Juvenile	12.0	12.0	1.7	1.7
RR7	M	Juvenile	11.9	11.0	1.2	2.4
RR2	M	Subadult	17.0	15.0	2.7	3.2
RR1	M	Adult	15.0	16.0	3.5	2.7
RR3	M	Adult	18.0	17.3	3.3	2.5
RR4	M	Adult	15.8	18.7	3.2	2.3
RR5	M	Adult	22.0	19.0	4.0	3.0

Of the five mongooses caught, three were adult males, one was a juvenile male, and one was a juvenile female (Table 4). Complete necropsies were conducted on four of the five mongooses. One necropsy (Species ID HA4) included external measurements only and age for this animal was based solely on body length. The carcass of one mongoose was not recovered, therefore a necropsy was not conducted (Species ID HA5). Age and sex for this mongoose was based upon the data collector noticing that the animal was large and testes evident.

Table 4. *Necropsy results for mongooses (Herpestes auropunctatus) trapped at Ka'āpahu, Haleakalā National Park, 2002.*

Species ID	Sex	Age	Weight (g)	Measurements (cm)	Gut Contents	Reproductive Status	Amount of Fat
HA3	M	Subadult	540	Tail 21.8 Body 25.3 Hind foot 6.0 Ear 2.5	Bait and leaves in stomach, slimy greenish brown and brown liquid in intestines	Testes inguinal	Very little throughout body
HA2	M	Adult	900	Tail 22.0 Body 33.0 Hind foot 4.0 Ear 2.7	Bait, leaves and dirt in stomach; green and brownish red mucous in intestines	Testes descended	Noticeable: fat on the hind quarters
HA1	M	Adult	1060	Tail 21.0 Body 35.0 Hind foot 4.2 Ear 2.9	Bait and leaves in stomach; green and brown liquid in stomach.	Testes descended	Throughout body; subcutaneous & mesentery
HA4	F	Juvenile	Not taken	Tail 13 Body 11 Hind foot 1.4 Ear 1.5	Not taken	Not taken	Not taken
HA5	M	Adult	Not taken	Not taken	Not taken	Not taken	Not taken

Gut contents varied and included trap bait, leaves and dirt in stomach, and brown, green liquid or mucous in intestines. Of the three male mongooses necropsied, two were sexually mature. The occurrence of fat in the three mongooses varied from very little fat throughout the body to substantial amounts of mesentary and subcutaneous fat.

Large Mammals

Signs of feral pigs, axis deer, and feral goats were continuous and numerous throughout the entire transect (Figure 5). Pigs were not seen, but one was heard along the transect, and pig signs (feces, digging of ground, pig trails, and rubbing against scrub) were observed along the transect from 275 to 1,180 m (900 to 3,880 ft). Fresh pig digs and feces were found along the entire transect. Fresh, well-established pig trails were found from 824 m (2,720 ft) elevation to sea level.

Two goats were seen from the transect at 200 m (650 ft) and 500 m (1,640 ft), and four goats were heard along the transect as high as 1,030 m (3,400 ft). Axis deer were not heard or seen during the surveys. Evidence of vegetation damage by axis deer (rubbing) was not observed. The only evidence of possible axis deer presence at Ka'āpahu during this survey was feces and tracks; however, these are indistinguishable from goats' feces and tracks.

Discussion and Recommendations

Although the trapping for rats, mice, and mongooses did not extend to sea level, it is likely that these animals occur at elevations below the monitoring stations. Black rats and mice occur in all habitat types at HALE from sea level to the park's 3,037 m (10,023 ft) summit (HALE unpubl. data). Black and Polynesian rats are abundant in low- and mid-elevation forests in Kīpahulu Valley (Sugihara 1997, HALE unpubl. data). Polynesian rats and mice are found in all habitats from sea level to higher elevation rainforests (Sugihara 1997, HALE unpubl. data). Norway rats are common at lower elevation throughout Hawai'i (Kramer 1971, Tomich 1986).

The presence of mongooses at Ka'āpahu was not unexpected. Mongoose populations are highest in areas below 610 m (2,000 ft) elevation, but are found in small numbers above 2,424 m (8,000 ft) elevation in sub-alpine and alpine habitats (Simons 1983, Stone and Loope 1987, Natividad Hodges 1994, Hays 2000, Natividad Hodges and Nagata 2001). Mongooses have been seen and captured in areas adjacent to Ka'āpahu at 1,515 m (5,000 ft) above Manawainui Valley and throughout Kīpahulu Valley as high as 1,940 m (6,400 ft) elevation in rainforest habitats (HALE unpubl. data).

Necropsy results on mongooses from this inventory are similar to those collected from HALE's predator control trap lines (HALE unpubl. data). Stomach contents are common items used as bait for traps. The green and greenish brown mucous found in intestines is commonly found in mongooses from HALE's predator control program and is probably digested bait and vegetation. The live catch trapping method for mongooses used in this survey allowed time for bait digestion and affected gut content identification. The varying fat content of the three mongooses is also similar to that of mongooses caught in HALE's predator control program in other locations of HALE.

Cats have been caught in other areas of HALE with similar habitat and are likely to occur at Ka'āpahu. Cats are difficult to detect and to capture with traps because of their stealthy, secretive nature. Data from HALE's trapping program from 1989 to 2004 show that the number of trap days necessary to capture one cat in forested and subalpine areas at HALE ranges from 936 to 19,635 trap days. Increasing the trapping effort may have increased the likelihood of capturing cats at Ka'āpahu.

Dogs were seen and heard in the lower elevations of Ka'āpahu outside of survey times. Hunting with dogs occurs at Ka'āpahu at elevations below 600 m (2,000 ft) and in adjacent areas. We have occasionally observed stray hunting dogs in the lower elevations of Ka'āpahu while conducting routine feral animal management work. Stray hunting dogs have the potential of driving feral goats, pigs, and axis deer into the higher elevations of Ka'āpahu and Manawainui where more native forest occurs.

Although axis deer were not seen or heard along the transect, they are likely to occur at Ka'āpahu. We continuously observe and receive daily reports of axis deer in the Kaupō area, which is less than 3.1 km (5 mi) from Ka'āpahu. Based on feral animal management observations, HALE staff estimates the deer population in the Kaupō area at 150-200 individuals as of March 2007. We have also seen axis deer in the adjacent State Manawainui hunting Unit A. Therefore, some of the feces and dropping observed during the survey were likely from axis deer.

Feral pig and feral goat observations and signs in Ka'āpahu during this survey were not unexpected. Pigs were seen during the development of the transect. The high frequency of pig and goat signs suggests that there are high numbers of these animals in Ka'āpahu. That feral pigs and feral goats occur in large numbers in areas surrounding Ka'āpahu has been well documented in HALE previously (Stone and Loope 1987, HALE unpubl. data).

The damage to native Hawaiian ecosystems and species by non-native mammals is well documented (Simons 1983, Banko 1988, Cuddihy and Stone 1990, van Riper and Scott 2001). Pigs and goats have damaged landscapes and vegetation. Mongooses and cats are primary predators of endangered Nēnē (Hawaiian Goose, *Branta sandvicensis*) and 'Ua'u (Hawaiian Petrel, *Pterodroma sandwichensis*) at HALE, with a single predator responsible for the deaths of large numbers of Nēnē and 'Ua'u (Simons 1983, Banko 1988, Natividad Hodges 1994, Baker and Baker 1996, Natividad Hodges and Nagata 2001). HALE field staff has observed mongooses climbing trees in Kīpahulu Valley. Forest bird remains have been found in the gut contents of mongooses caught in HALE rainforests (HALE unpubl. data). Rats, mongooses, cats, and dogs prey upon native bird and insect populations. Rats also have been observed consuming native vegetation (P.Welton, pers. comm.). Persistent populations of non-native mammals could cause further detrimental effects to the native biota at Ka'āpahu.

Axis deer, the relatively new threat to native ecosystems on Maui, occur in the adjacent state hunting unit. This unit receives very little hunting pressure because the area has no public access (John Medeiros, pers. comm.). Without any current deer population control measures, axis deer populations are likely to increase at Ka'āpahu in the near future.

The benefits of effective control of all of these animals are also well documented. The upper elevations of Kīpahulu have shown remarkable vegetation recovery with the removal of pigs and goats (Anderson and Stone 1993). The endangered 'Ua'u at Haleakalā has increased dramatically since the control of rats, mongooses, cats, pigs, and goats (Natividad Hodges and Nagata 2001, HALE unpubl. data).

Native forest birds and patches of native and rare vegetation occur in Ka'āpahu (Welton and Haus 2005). It is important to control non-native mammal species to allow habitat and species to recover. The building of feral animal control fences, together with simultaneous control of non-native mammals in Ka'āpahu, should be considered as a management priority for the area.

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APPENDIX I CHECKLIST OF FOREST BIRDS AT KA`ĀPAHU, HALEAKALĀ NATIONAL PARK

		Occurrence	Origin	Status
Order COLUMBIFORMES				
Family COLUMBIDAE				
Spotted Dove	*Streptopelia chinensis* (Scopoli, 1786)	Probable	Non-native	Common
Zebra Dove	*Geopelia striata* (Linnaeus, 1766)	Probable	Non-native	Common
Order PASSERIFORMES				
Family SYLVIIDAE				
Subfamily SYLVIINAE				
Japanese Bush-warbler	*Cettia diphone* (Kittlitz, 1830)	Confirmed	Non-native	Common
Subfamily TIMALIINAE				
Hwamei	*Garrulax canorus* (Linnaeus, 1758)	Confirmed	Non-native	Common
Red-billed Leiothrix	*Leiothrix lutea* (Scopoli, 1786)	Confirmed	Non-native	Common
Family ZOSTEROPIDAE				
Japanese White-eye	*Zosterops japonicus* Temminck & Schlegel, 1847	Confirmed	Non-native	Common
Family STURNIDAE				
Common Myna	*Acridotheres tritis* (Linnaeus, 1766)	Probable	Non-native	Common
Family CARDINALIDAE				
Northern Cardinal	*Cardinalis cardinalis* (Linnaeus, 1758)	Confirmed	Non-native	Common
Family FRINGILLIDAE				
Subfamily CARDUELINAE				
House Finch	*Carpodacus mexicanus* (Muller, 1776)	Probable	Non-native	Common
Subfamily DREPANIDINAE				
Maui Parrotbill	*Pseudonestor xanthophrys* Rothschild, 1893	Unlikely	Native	Endangered[1]
Maui 'Amakihi	*Hemignathus virens wilsoni* (J. F. Gmelin, 1788)	Confirmed	Native	Common
Maui Nukupu'u	*Hemignathus lucidus affinus* Lichtenstein, 1839	Unlikely	Native	Endangered[2]
Maui 'Alauahio	*Paroreomyza montana newtoni* (Wilson, 1890)	Confirmed	Native	Common
Maui 'Akepa	*Loxops coccineus ochracea* (J. F. Gmelin, 1789)	Unlikely	Native	Endangered[2]
`Ākohekohe	*Palmeria dolei* (Wilson, 1891)	Unlikely	Native	Endangered[1]
`I`iwi	*Vestiaria coccinea* (Forster, 1780)	Confirmed	Native	Common
`Apapane	*Himatione sanguinea sanguinea* (J. F. Gmelin, 1788)	Confirmed	Native	Common
Po'ouli	*Melamprosops phaeosoma* (Casey & Jacobi 1974)	Unlikely	Native	Endangered[3]

Family PASSERIDAE				
House Sparrow	*Passer domesticus* (Linnaeus, 1758)	Probable	Non-native	Common
Family ESTRILDIDAE				
African Silverbill (formerly Warbling Silverbill)	*Lonchura cantans* (J. F. Gmelin, 1789)	Probable	Non-native	Common
Nutmeg Mannikin	*Lonchura punctulata* (Linnaeus, 1758)	Probable	Non-native	Common

CHECKLIST KEY

Occurrence
Confirmed = Confirmed visual or audio detection of species during surveys
Probable = Probably occurs in suitable habitat in Ka'āpahu based on information on distribution of species from other sources including literature cited in this report.
Unlikely = Unlikely to occur in Ka'āpahu based on information on distribution of species from other sources including literature cited in this report.

Origin
Native = occurs naturally, not brought by humans
Non-native = alien introduction by humans

Status
Common = certain to be detected in proper habitat or season
Endangered = Federally listed as endangered
1 = regularly detected in proper habitat or season, although in low numbers
2 = rarely detected because of low population size
3 = maybe extinct

REFERENCES FOR TAXONOMY AND NOMENCLATURE

Integrated Taxonomic Information System Database. 2005. http://www.itis.usda.gov. Data retrieved September 1, 2005.

Pratt, H. D., P. L Bruner, and D. G. Berrett. 1987. A Field Guide to the Birds of Hawai'i and the Pacific. Princeton University Press. Princeton, New Jersey.

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APPENDIX II CHECKLIST OF NON-NATIVE MAMMALS AT KA`ĀPAHU, HALEAKALĀ NATIONAL PARK

	Occurrence
Order RODENTIA	
Family MURIDAE	
Black rat *Rattus rattus* (Linnaeus, 1758)	Confirmed
Norway rat *Rattus norvegicus* (Berkenhout, 1769)	Probable
Polynesian rat *Rattus exulans* (Peale, 1848)	Probable
House mouse *Mus musculus* Linnaeus, 1758	Probable
Order CARNIVORA	
Family CANIDAE	
Domestic dog (feral) *Canis lupus* Linnaeus, 1758. (Note: *Canis familiaris* Linnaeus 1758 is an invalid junior synonym)	Confirmed[1]
Family HERPESTIDAE	
Small Indian mongoose *Herpestes javanicus* (E. Geoffroy St.-Hilaire, 1818)	Confirmed
(Note: *Herpestes auropunctatus* (Hodgson, 1836) is an invalid junior synonym, but more commonly used in Hawai'i. Therefore, *Herpestes auropunctatus* is used in this document).	
Family FELIDAE	
Domestic/house cat *Felis silvestris* Schreber, 1775	Probable
(Note: *Felis catus* Linnaeus, 1775 is an invalid junior synonym, but more commonly used in Hawai'i. Therefore, *Felis catus* is used in this document).	
Order ARTIODACTYLA	
Family SUIDAE	
Pig (feral) *Sus scrofa* Linnaeus, 1758	Confirmed
Family CERVIDAE	
Axis deer *Axis axis* (Erxleben, 1977)	Probable[2]
Family BOVIDAE	
Goat (feral) *Capra hircus* Linnaeus, 1758	Confirmed

CHECKLIST KEY

Occurrence

Confirmed = Confirmed visual or audio observations made along transect during survey

Probable = Probably occurs in Ka'āpahu based on distribution of species cited in other sources.

[1] = Confirmed visual or audio observations made along transect not during survey.

[2] = Feces and tracks were observed, but were not distinguishable from feral goat.

Invalid junior synonym = Taxonomic status where this name was used to describe the same species, but at a later date (i.e. the valid name was the first one used to describe the same species.)

RERERENCE FOR TAXONOMY AND NOMENCLATURE

Integrated Taxonomic Information System Database. 2005. http://www.itis.usda.gov. Data retrieved September 1, 2005.

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